

N73-16160
CR-128693



Final Report

EARTH RESOURCES DATA ANALYSIS SYSTEM

Contract No. NAS 9-12106

Prepared for

**CASE FILE
COPY**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Manned Spacecraft Center
Facility and Laboratory Support Branch
Houston, Texas 77058

1746FR-1

October 1972

***AEROJET
ELECTROSYSTEMS
COMPANY***

AZUSA, CALIFORNIA

Final Report

EARTH RESOURCES DATA ANALYSIS SYSTEM

Contract No. NAS 9-12106

1746FR-1

October 1972

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Manned Spacecraft Center
Facility and Laboratory Support Branch
Houston, Texas 77058

Prepared by

AEROJET ELECTROSYSTEMS COMPANY
1100 W. Hollyvale Street
Azusa, California 91702

CONTENTS

	<u>Page</u>
SECTION 1 - INTRODUCTION	1-1
1.1 Overview	1-1
1.2 Physical Description	1-6
1.3 Program Chronological Summary	1-7
1.4 Acknowledgement	1-9
SECTION 2 - ERL-DAS SYSTEM	2-1
2.1 Computer System	2-3
2.2 The Multispectral Input System	2-3
2.2.1 Input Data Capability	2-5
2.2.2 Data Buffering	2-5
2.2.3 Channel Enable	2-6
2.2.4 Overflow Indication and Output Transmission	2-6
2.3 PCM and ADAS Interfaces	2-6
2.4 Bench Test Unit	2-7
2.5 Optical Subsystem	2-8
2.6 Display Subsystem	2-10
SECTION 3 - ERL-DAS SOFTWARE	3-1
3.1 The MSDS Programs	3-1
3.2 The S192 Processing Programs	3-3
3.3 The PMIS Processing Programs	3-5
3.4 The Optical Program (OSSS) Program Description	3-6
3.5 Independent Handlers	3-7
SECTION 4 - APPLICABLE DOCUMENTATION	4-1
4.1 Reference Documents	4-1
4.2 O&M Manual	4-1
SECTION 5 - ERL-DAS SPECIFICATION COMPLIANCE	5-1
SECTION 6 - CONCLUSIONS AND RECOMMENDATIONS	6-1
6.1 Conclusions	6-1
6.2 Recommendations	6-1

Section 1

INTRODUCTION

This document is the final report of the Earth Resources Laboratory Data Analysis System (ERL-DAS), Contract No. NAS 9-12106. This effort completes Article XIV.A.2 of this contract.

The objectives of this contract were to design, fabricate, install and verify operation of a data analysis system to be used for the processing, imaging, and recording of Earth Resources Sensor Data.

Its principal applications include processing of 26 channel multispectral data recorded on high density-PCM formatted analog tape, radiometric data acquired by the Passive Microwave Imaging System (PMIS), Skylab S192 data, and multispectral data recorded on color or black and white film transparencies. Computer software is included for operational processing of sensor input data with versatile general handler packages suitable for system expansion. A brief description of the ERL-DAS software is contained in Section 3 of this report. The ERL-DAS system (excluding the Optical Input System) is shown in Figure 1-1.

1.1 OVERVIEW

On 29 June 1971 the Microwave Division of Aerojet-General Corporation initiated the design and fabrication of the Earth Resources Laboratory Data Analysis System (ERL-DAS) for the National Aeronautics and Space Administration under Contract NAS 9-12106. The approach taken for this system emphasized versatility and flexibility so as to satisfy current and future data analysis requirements. It incorporates innovative and imaginative concepts where these can be implemented within well-established technology, and where practical makes use of standard commercial products to minimize redundant design effort.



Figure 1-1. ERL-DAS System

One source of earth resources data which must be processed by the ERL-DAS is image data recorded on film. This data typically is multispectral and is recorded either as separate black and white images, one for each spectral band, or as one image on color film in which the film dyes contain the spectral information. It is necessary to process this image information as multispectral point-by-point data to support terrain signature analysis or image enhancement processing. Thus it is necessary in the case of separate images to precisely register each of the input films; and for the single color film to separate each spectral component from the film dyes. This subsystem must be integrated into the overall DAS to serve as one of the data input sources.

There are several key aspects of the system design. An all-electronic approach to the registration process is used which provides maximum flexibility, offers significant simplification of the optical and mechanical sections, and increased accuracy and reliability. The optics are implemented using a single lens system and prism which has the attendant features of greatly simplified alignment, high reliability-maintainability, and reduced cost.

Complete control of the scanning process is available to the data analyst. Any type of scanning can be accomplished for automatic registration, correlation studies, or the high-resolution digitization of a selected arbitrarily shaped region such as a training sample area. Complete access to all output devices and centralized control is provided by the interactive operator control console (IOCC).

A unique optical subsystem has been developed which incorporates specially designed components in a novel arrangement that ensures optimum system performance with a minimum amount of hardware. The subsystem design is modular in the sense that components are combined in a subsystem which is responsive to the subject system requirements. Provision for modification of components within the subsystem exists thereby allowing future modification of the equipment for the execution of other related tasks. An example of the modular structure of the subsystem is the ability to replace the fixed magnification relay lens with a zoom lens to extend the range of the scanned area below the inch-by-inch format.

The magnetic tape input subsystem provides the ability to read the 13-channel, 10,000 bit-per-inch remote sensor data tapes, a single channel PCM input, and the ADAS input. The design of this system is very similar to the proven design developed by Aerojet for the PMIS-Data Analysis Station, and its flexibility in handling a wide variety of data formats, including reformatted Skylab S192 data has been established. This input system incorporates those refinements and improvements typical of a second generation design after hands-on operational experience.

Control and monitoring of the Data Analysis System is accomplished with the Model SG-D2400 high-speed data processor which includes options tailored for this application, together with a tape search system and an interactive operator control console (IOCC).

All devices and interfaces which are controlled and monitored by the processor, including the processor itself, are supported by complete diagnostic routines for maintenance, adjustment, and troubleshooting use. I/O handler packages which offer a clean interface, and where applicable, linkage to the IOCC are provided for all devices. These handlers are assembled, together with the necessary application and data dependent coding, to form operational control and monitoring programs. The MOS operating system supports batch processing operations and program access, which further expands the flexibility of the system, and allows the use of the system for secondary support activities.

The proper man-machine interface for the control and monitoring of the Data Analysis System functions is a key to the successful operation of the system. This interface provides a central point of control, easy input and display of control and monitor parameters, interactive bidirectional responses, and a high degree of flexibility to accomplish a wide variety of image processing tasks. This capability is provided by the control panel concept offered by the Model SG-D2500P Interactive Operator Control Console (IOCC).

The conventional approach to such a requirement is to provide an assemblage of switches and lights. The rigidity of this approach is clear.

The use of a serial character device such as a teletype or CRT terminal eases the problem of communicating data values and alphanumeric data, but this method is slow and awkward. The Aerojet IOCC provides a highly flexible control panel which provides logically 800 switches, each of which can assume one of 64 positions. Each such switch is displayed as a letter, character, or numeral, and can be changed either by the operator or by the processor. The entire display or selected portion, can be completely changed in less than a second. Direct correspondence between the processor, the display, and the keyboard marker assures absolute communications and rapid access to any position.

Image data is displayed via the Aerojet Model SG-D 2116-P-M-L Display Unit which provides for the storage of a one-level image in addition to the normal full color or pseudo-color image. This one-level image is normally used as an overlay of the regular image. The spatial resolution of this image is identical to that of the normal image. The SG-D 2116-P-M-L Display units are supplied with a system to communicate between the one-level image and the external data source, in this case the SG-D 2400 Data Processor, optimized to provide a four corner, completely variable geometry cursor with the minimum of information transfer. The resulting cursor frame is one picture element wide by one TV line high. Complete spatial resolution is provided with the transmission of less than 2000 nine-bit words. This compares with the approximately 20,000 words that would have to be transmitted to define an entire single level image. The cursor is generated in the hardware and stored on three additional tracks of the display disc memory. These tracks are provided with flip-flop feed around so that cursor information appears constantly on the screen during all cursor operations, without the annoying flicker generated in the writing of a new cursor.

The intensity of the cursor outline is automatically adjusted in the hardware to provide an optimum-contrast with surrounding scene data in true color, pseudo-color and black and white display operating modes. The formulas used to perform this cursor intensity adjustment are as follows:

A Model SG-D 2600 Strip Film Camera provides the ability to record onto film, in either color or black and white, a high-resolution hard copy of the digital image data processed by the Data Analysis System. The design concept of this camera is based on the proven design used for the PMIS-DAS. Adequate controls are included to adjust for any black and white or color film of adequate sensitivity (Kodak 2448 Color Ektachrome and Acrographic Plus-X are suitable).

1.2 PHYSICAL DESCRIPTION

The separable physical entities of the ERL-DAS system are tabulated below.

- a. A three bay rack assembly consisting of the following, left to right:

Rack A

- High resolution digitally driven color strip film recorder.

Rack B

- Multispectral PCM and ADAS input electronics
- Optical input system electronics
- Miscellaneous control and interface circuitry
- Power supplies

Rack C

- A Varian 620F computer including the following subunits
 - 16K core memory
 - Two tape controllers
 - Two buffer interlace controllers
 - Two block transfer controllers
 - Three priority interrupt modules

- IRIG A time code reader and generator
- Expansion space
- b. Two Ampex 150 IPS Tape Transports
- c. A FR-2000 14 track wide band analog tape recorder/reproducer
- d. One 300 cards/min card reader
- e. A high resolution multispectral optical input system
- f. A system control console consisting of the following:
 - Color display
 - IOCC alphanumeric display/keyboard
 - Display/cursor-light pen electronics
 - Miscellaneous interface electronics
- g. A 64 character, 132 print position, high speed line printer

1.3 PROGRAM CHRONOLOGICAL SUMMARY

On 29 June 1971, the design and fabrication of the Earth Resources Laboratory Data Analysis System was initiated.

A Design Review meeting was held at the Aerojet facilities on 19 and 20 August 1971 to discuss in detail the Design Review Report.

The detailed design of the optics portion of the ERL-DAS was presented to NASA representatives during the design review meeting of 27 and 28 September 1971. Software coding and hardware fabrication was continuing on schedule.

Preliminary checkout of the electronic subsystems was initiated during the month of January 1972.

A meeting with NASA/MTF and their support personnel was held during the month of February 1972 to clarify and agree upon the details of the Acceptance Test Procedure previously submitted in rough draft form to NASA/MTF. Software punching, assemblies and checkout were initiated during this month.

During the month of March 1972 problems with the Varian CPU became severe. Although problems could be worked around, the CPU problem caused significant delay in program assemblies and checkout.

The preliminary acceptance test of the Multispectral Optical System was performed at Perkin Elmer and the unit was installed at Aerojet's facility during the month of April 1972. A significant portion of the hardware checkout was completed.

A new data processor (CPU) and slave memory were installed in May 1972 due to Varian's inability to correct problems in the original CPU. Checkout of essentially all hardware and a large portion of the software was completed during this month.

The preliminary acceptance tests at the Aerojet facility began on 27 June 1972 and were completed on 1 July 1972. These tests were witnessed by NASA MTF, Lockheed, AGC/QC, and DCASO representatives.

The ERL-DAS system was shipped to NASA MTF on July 7, 1972 and was received at MTF on July 10, 1972. Aerojet-General Corporation's employees arrived at MTF July 11, 1972 and began system setup and checkout in preparation for final acceptance testing. The system was operational July 12, 1972.

Acceptance testing of the ERL-DAS was conducted through July 22, 1972. The system was accepted with the specific exceptions noted on the signed DD250. At this time a partial delivery was made of the supplementary manuals of the O&M manual package.

Two (2) subsequent trips to NASA MTF by Aerojet and HRB Singer personnel corrected the deficiencies noted in the DD250 obtained upon completion of the system acceptance test.

The O&M manual has been delivered to NASA Houston completing all requirements under Contract NAS 9-12106.

1.4 ACKNOWLEDGEMENT

Aerojet ElectroSystems Company wishes to acknowledge the invaluable assistance provided by NASA technical and contract personnel in the successful completion of the Earth Resources Laboratory-Data Analyses System contract and extends special thanks to Messrs. Jim Derbonne, Bob Dupstadt, Bill Edwards, Dave Harvey and Sid Whitley.

Section 2

ERL DAS SYSTEM

The Earth Resources Laboratory Data Analysis System is designed with the capability to reduce a broad range of remote sensor data. The output of the reduction operation may be presented in several different formats. The system will accept sensor data that has been encoded using digital magnetic tape, PCM encoded analog magnetic tape, including 24-channel multispectral data, and photographic film, either black and white or color transparencies.

The system output may be recorded on digital tape for further processing, displayed on a high resolution color TV monitor, recorded on 9-1/2 inch color or black and white film or listed on a high-speed line printer. The basic system includes the following major components.

- a. A 14-channel broadband instrumentation tape reproducer/recorder.
- b. A high-speed, general-purpose computer.
- c. Two 150-ips digital tape recorders/reproducers.
- d. A high resolution three-color TV display used to provide raster presentations of sensor data for evaluation by the system operator. Data may be presented in true color, pseudo color, or black and white. A light pen/cursor system is provided for delineation of data areas of interest.
- e. A high-resolution, 9-1/2-inch-wide strip film camera system capable of recording on film data presentations in color or black and white.
- f. A versatile Interactive Operator Control Console providing complete operator-processor communication and control.
- g. A multispectral optical input subsystem capable of high-resolution scanning and digitizing of black and white multispectral transparencies or color transparencies.

These major system components are coupled to the high-speed, general-purpose computer through specially designed interface units designed for maximum data transfer rate, with the minimum of software monitoring required for their operation.

The 14-channel broadband instrumentation tape reproducer/recorder is a 1-inch tape Ampex FR-2000 with a set of direct playback electronics and the associated equalizing networks to allow the playback at tape speeds from 1-7/8 to 120 inches per second. In addition, there is one (1) set of direct record electronics that may be used with the Tench Test Unit to generate analog tapes in selected data formats. The FR-2000 is also equipped with a servo speed control to play back data tapes at continuously variable tape speeds, and to allow matching of the data input rate to the data reduction processing speed.

The high-speed, general-purpose computer is a Varian Model 620F, 16-bit word length, equipped with two (2) Buffer Interface Controllers, (2) Block Transfer Controllers, two (2) 9-track 150 ips tape controllers and 16,000 words of memory. An optional instruction set including a hardware multiply/divide capability is included. A high-speed line printer and 300 card/min. card reader and required controllers are also included in the computer subsystem.

The three-color TV display system uses a Conrac 19-inch RGB monitor with a 48-track data disc memory unit which is used for monitor display, refresh. The display refresh memory provides a constant flicker-free presentation of the displayed data by providing the color or black and white information at standard television line and field rates. The combination of the computer and the data disc memory provides a completely flexible scan conversion system which presents the data at a standard television rate regardless of the scan rate used when the data was acquired.

The display system is implemented to provide an overriding cursor. The cursor information is stored on the data disc memory on tracks separate from the image data thus leaving the original image data intact. Control of the cursor size and position on the screen may be obtained from input from the numeric display keyboard. In addition, movement and modification of the cursor corners may also be accomplished utilizing a light pen interface.

The multispectral optical system consists of a high-resolution Beta Instrument flying-spot scanner, control electronics and a Perkin-Elmer multispectral optical subsystem. The optical subsystem accepts up to four (4) black and white film transparencies or one (1) color transparency with the required optics to separate the color transparency into RGB data. Data is digitized to one (1) part in 1023 (10 bits).

Figure 2-1 is a block diagram of the ERL DAS system showing input/output and subsystem signal flow.

2.1 COMPUTER SYSTEM

The Varian 620F computer system consists of a main frame and two (2) expansion chassis. The system contains the following features.

- a. 16 K memory.
- b. Optional instruction set including hard-wire multiply and divide capability.
- c. Two (2) Buffer Interface Controllers providing automatic I/O transfer.
- d. Two (2) Block Transfer Controllers providing high-speed direct I/O transfer with memory.
- e. Two (2) TM16 9-track tape transports and controllers providing tape speed of 150 ips at 800 bpi (12 kHz transfer rate).
- f. One (1) 300-card-per-minute card reader and controller.
- g. One (1) high-speed line printer and controller providing 132 columns, 64 characters at a rate of 245 to 1100 lines per minute.
- h. Three (3) 8-level priority interrupt modules.

2.2 THE MULTISPECTRAL INPUT SYSTEM

The multispectral data is recorded on 14 tracks by a magnetic tape recorder. Thirteen (13) of these tracks may be read at one time by the interface system. Twelve (12) of these tracks contain two (2) sensor values each, and these

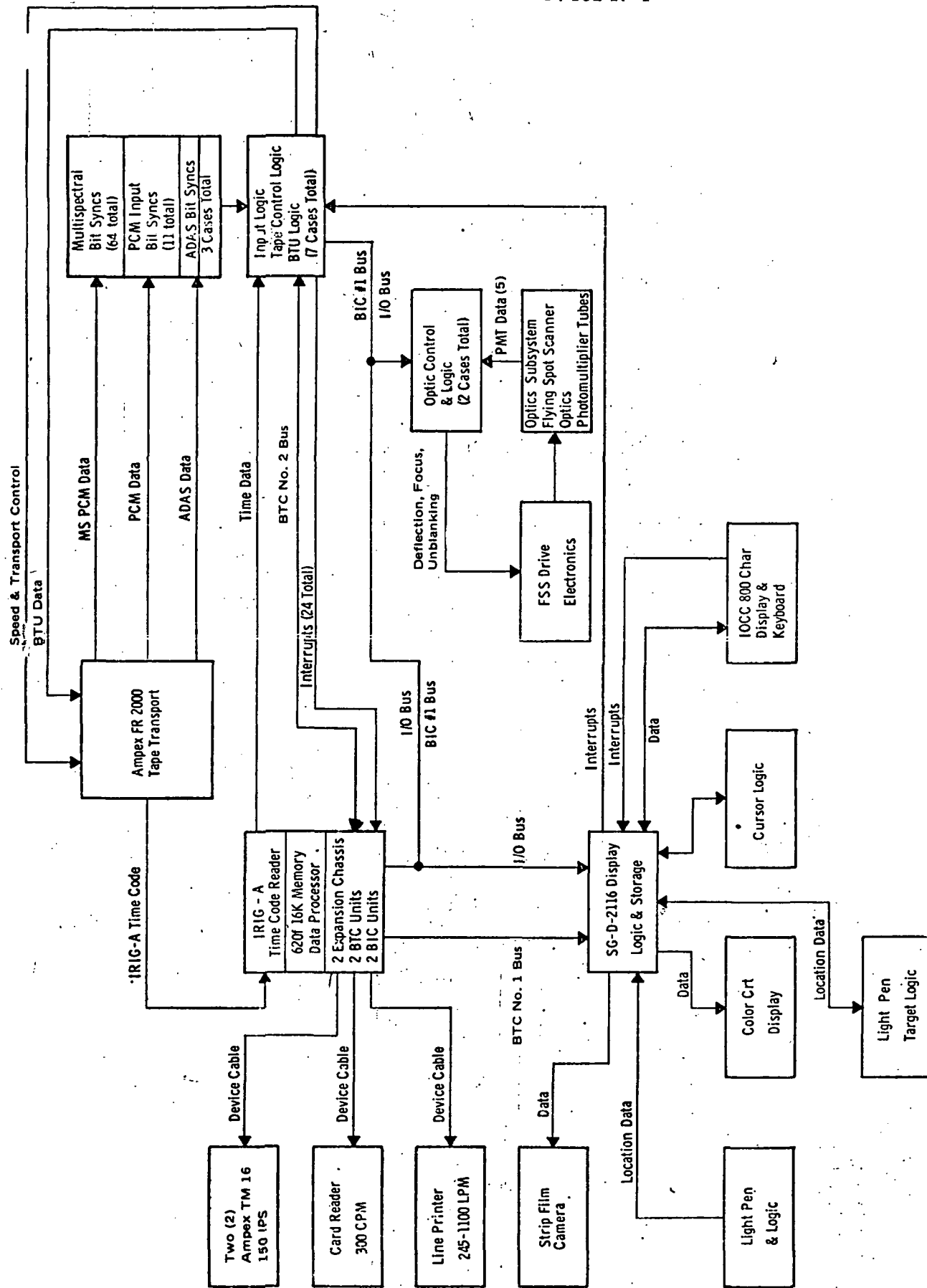


Figure 2-1. ERL-DAS System Block Diagram

sensor values are time-division multiplexed. One (1) track contains instrumentation support data. These 13 tracks are always recorded by the Multispectral Scanner System at a density of 10,000 bits per inch. Each of these 13 channels are modulated with bi-phase L pulse-code modulation. A data value is made up using eight (8) sequential bits. These eight (8) sequential bits become a sensor word. There is a specific 16-bit frame sync pattern that appears once every 1572 words and corresponds to the starting point of the multispectral scan. The fourteenth channel contains an IRIG standard time code. This time code is used by the ERL-DAS for tape search purposes. The salient features of the ERL-DAS MSDS Input Subsystem are listed below.

2.2.1 INPUT DATA CAPABILITY

- a. Thirteen (13) separate input channels are provided, each capable of operating from a PCM input encoded in Bi-phase L.
- b. All channels are capable of acquiring and locking onto the data at any bit rate from 10 kbps to 200 kbps and 350 to 750 kbps.
- c. The foregoing bit ranges are covered by 5 separate bit synchronizers. Selection of the bit synchronizers and bit synchronizer center frequencies are remotely programmable to the required resolution via digital logic signals. Selection also commands the FR2000 tape recorder to the correct speed for the 10,000 bpi density.
- d. Proper operation of the subsystem requires the successful detection of a 16-bit frame sync pattern for each enabled input channel. The appropriate 16-bit sync pattern is always the same for each input channel, but the basic sync pattern is defined by a 16-bit word supplied by the data processor and is completely variable.

2.2.2 DATA BUFFERING

- a. Each channel is provided with a total of 64 bits of buffer capacity. Sixty-four bits allow the reception, in a given channel, of a total 79 bits of skew before the buffering capacity is overloaded.

- b. Loading of the buffer section of each channel is independent of all other channels and commences when the appropriate 16-bit sync pattern defined by the output from the data processor is detected by the channel logic.

2.2.3 CHANNEL ENABLE

- a. Each of the 13 input channels may be remotely enabled by digital logic.
- b. A signal is generated by each channel, which may be remotely sensed, and indicates the successful acquisition of the appropriate frame sync by the channel.
- c. A signal is generated by the subsystem indicating when all enabled channels have successfully transferred the first data word of the first acquired frame.
- d. A signal is reissued as all enabled channels have received each additional word.

2.2.4 OVERFLOW INDICATION AND OUTPUT TRANSMISSION

- a. The subsystem acknowledges the transmission to an external device of the data stored in one section of the data buffer by effectively clearing that section of the buffer and allowing new data to be stored.
- b. If the external device does not withdraw the data from the channel buffer within the allowed bit times, an overflow indication is supplied by each channel.

To minimize data manipulation and increase system throughput, each channel may be selectively enabled to transfer either one or both eight-bit values of a 16-bit input word. Only those channels so enabled are transmitted thereby minimizing the data transfer operations.

2.3 PCM AND ADAS INTERFACES

The PCM input interface provides the capability to process a wide variety of PCM recorded data. This interface provides

- a. Input of one (1) channel of PCM data at any data rates from 180 to 100,000 bps using 10 independent bit synchronizers.

- b. Data processor selection of the bit synchronizer and the 2:1 fine adjustment of center frequency independent of tape reproduce speed.
- c. Data transfer of any word length from 5 to 16 bits with dynamic data processor selection of word length.
- d. Data transfer by programmed control or by automatic block transfer using the high-speed priority channel.
- e. Highly flexible sync and decommutation of the data in association with the processor.

The ADAS input is required to provide the housekeeping data, such as time, aircraft parameters, and status which are used by some of the data collection systems. This subsystem will acquire, decode, pack, input and list ADAS data reproduced from the FR2000 analog magnetic tape in the FM Wideband II mode. The input rate can be adjusted from 12.5 to 25 K bits/sec (nominal is 23 K bps) with automatic thresholding of the frame sync pulse. Data transfer is by programmed control with transfer initiated by a frame sync interrupt and a data word available interrupt.

2.4 BENCH TEST UNIT

Checkout and verification of the PCM inputs to the ERL-DAS requires a device which can generate the desired test signals both to test and adjust the hardware and to create analog test tapes. This unit provides:

- a. Thirteen (13) parallel outputs with line drivers.
- b. Output encoding of the test data as bi-phase L, RZ, or NRZ as selected by digital logic signals.
- c. Data rates from 146.5 to 1,200,000 bps as selected by logic signals.
- d. Any desired bit pattern, either cyclic or dynamically varying.
- e. Automatic block data transfer so the processor is available for other tasks.

2.5 OPTICAL SUBSYSTEM

2.5.1 OPTICS

The optical subsystem receives the light from the spot illuminated on the flying spot scanner (FSS) and transmits this light through the film to the photomultiplier pickups. The optic subsystem can be used, depending upon the placement of the film, either to scan up to four film images (black and white) or to separate the dye layers of color film into the spectral components of red, green, and blue. The optics subsystem, shown in Figure 2-2, consists of the following components:

- a. **Color Separation Lens.** This lens projects the light through the beamsplitter onto the color separation film gate. This lens also provides the 1.1 magnification to match the FSS size to the film sizes.
- b. **Beamsplitter.** This beamsplitter intercepts the unmodulated light and transfers approximately 8 percent of the luminance to the reference PMT. This measure allows the electronics to compensate for variations in source illuminance.
- c. **Color Separation Gate.** In color separation operations, the color film located at this point is scanned by the FSS. This gate is left open when multi-image registration is used.
- d. **Relay Lens.** The relay lens couples the light with the beamsplitter prism with unity magnification.
- e. **Prism.** The prism separates the incident light into four separate displaced images in which each image contains a discrete portion of the incident spectral energy, thus facilitating both color separation and multi-image scanning. The prism reflects the blue component of light at the first beamsplitting surface with a blue reflecting dichroic interference filter, subsequently reflects the red component at the second beamsplitting surface with a red reflecting dichroic, and finally divides the green components into two equal intensity channels with a neutral density beamsplitter located at the third beamsplitting surface.
- f. **Film Gates.** The four (4) separate images generated in the prism are imaged onto the film gates when multiband operation is used.
- g. **Condenser Lenses.** The condenser lenses couple the modulated light from each of the film gates to the PMT's.

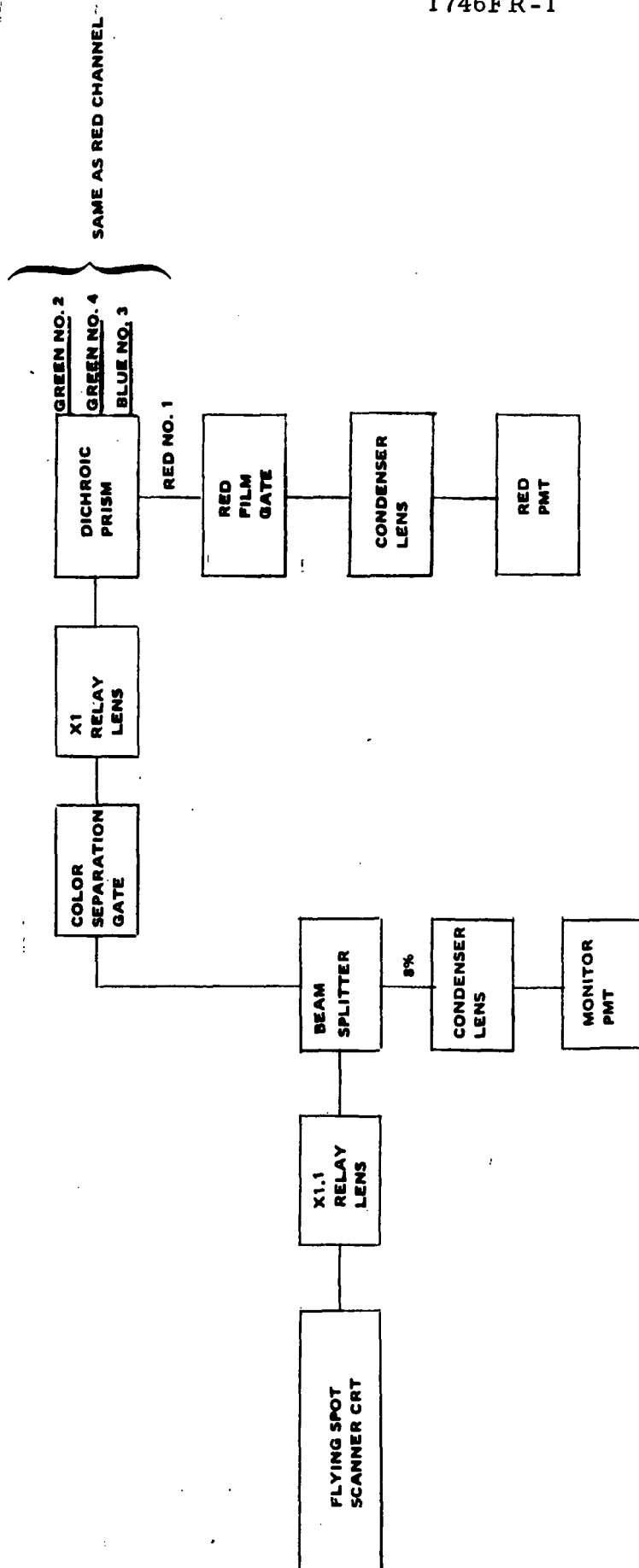


Figure 2-2. Optics Subsystem Block Diagram

2.5.2 OPTICAL ELECTRONICS SUBSYSTEM

The photographic electronic subsystem, under direction of the data processor, generates a precise optical input scan to the flying spot scanner (FSS) and receives the resultant output with photomultiplier tubes (PMT). It provides the control and data handling necessary to register one (1) to three film images to a reference image, and to scan digitize automatically the images to a high degree of accuracy following registration.

System scanning parameters are entered into the optical input electronics by means of the computer BIC buss. When used in conjunction with the OSSS software, the scanning parameters are operator-controllable from the IOCC.

2.6 DISPLAY SUBSYSTEM

The display subsystem consists of the following units:

- a. Five-bit true color, 6-bit pseudo color, high-resolution TV display.
- b. High-resolution strip film recorder option.
- c. Cursor, light pen, and light pen target option.
- d. Interactive Operator Control Console option.

2.6.1 TV DISPLAY

The TV display provides the capability of presenting digitally encoded data in high resolution images of pseudo color, true color or black and white. Changeover in operation between the pseudo-color and five-color modes is simply accomplished by changing a logic patch card.

The TV display consists of input buffer storage, a 3:1 write multiplexer, real time disc storage of 525 data lines, a 3:1 read multiplexer, color algorithm memories, test pattern generators, video D-A converters, timing logic and a 19-inch Conrac color monitor. Input storage consists of 135, 64-bit MOS shift registers. It provides storage of one complete display

line, 576 pixels with 15 bits per pixel. Under computer control, this input storage register may be loaded with up to 558 pixels asynchronous with the display timing. Upon load completion the line contents are then written on the disc at the line address previously transmitted by the processor on the input data lines. The 135, 1 Mbps shift register outputs are multiplexed to 45 write outputs providing a 3-Mbps data rate to the disc tracks. The disc provides real time storage of 525 data lines. Disc revolution is synchronous to the color monitor frame rate of 30 frames per second. Reading off the disc the 45 data lines are further multiplexed to provide 15 lines at 9 Mbps data rate per line. These 15 lines are applied directly to the three-color D-A converters (5 bits/converter) in the true color mode, or six of the fifteen lines are used as address information to the color algorithm memories, providing 64 colors, as described in the algorithm memories in the pseudo-color mode. The color algorithm is loaded into the memories either under computer control or manually by front panel switches. Black and white is provided by slaving the red and blue D-A converters to the green D-A converter. In the black and white mode, the green D-A input is derived directly from disc output only (the same six lines used as address lines to the color algorithm memories in the pseudo-color mode). In addition to normal data presentation, test pattern generators are available to provide data, bars, gray scale or a presentation of the color values stored in the color algorithm memories. The timing logic generates the horizontal and vertical scan rates and their associated sync pulses from the disc clock output. In addition, it synchronizes all functions of the display subsystem. The three D-A converters providing green, red, and blue video to the monitor have a response in excess of 20 Mbps. The Conrac monitor video response is in excess of 7 MHz.

The characteristics of the TV display are listed below:

- 525-line frame
- 30 frames/second
- 576 pixels/line

- 15 bits/pixel (6 bits black and white)
- 500 displayed pixels/line
- Asynchronous computer-controlled loading
- Input buffer capacity = 1 line (576 pixels)
- Rising raster, falling raster, single line update or fixed raster
- Maximum load rate — 60 lines/sec, 1 Mbps asynchronous/ input data line
- Simultaneous presentation of 64 pseudo colors
- Selection of 4096 color hues/pseudo color
- Capability of presenting up to 2^{15} colors in true color
- Color algorithm loadable either under computer control or from front panel switches
- Test Patterns — dots, bars, gray scale, contents of color algorithm memory
- Video Response — 7 MHz

2.6.2 CURSOR/LIGHT PEN OPTION

The display subsystem provides for the storage of one-level image in addition to the normal full color or pseudo-color image. This one-level image is used to provide a four-corner, completely variable geometry cursor overlay. The cursor frame is one picture element wide by one TV line high. Complete spatial resolution is provided with the transmission of less than 2000 nine-bit words. The cursor is generated in the hardware and stored on three additional tracks of the display disc memory. These tracks are provided with flip-flop feed-around so that cursor information appears constantly on the screen during all cursor operations.

The intensity of the cursor outline is automatically adjusted in the hardware to provide an optimum contrast with surrounding scene data in true color, pseudo color and black and white display operating modes. The formulas used to perform this cursor intensity adjustment is as follows:

If a given picture element on the screen is to be displayed as a cursor outline point, the values of the associated normal display picture element are examined as to intensity. If the most significant bit of any two colors is true, the cursor produces a full black picture element on the screen. If neither bit is true, the cursor produces a full white picture element on the screen.

The technique of storing the cursor information on the same storage disc used for the image guarantees precise image/cursor registration in all modes of display operation including falling or rising raster modes and allows processor routines to provide the necessary data manipulation to produce data zoom and other desired cursor functions without additional parameter inputs.

There are two modes of cursor operation: (1) move existing cursor and (2) modify cursor shape and size. Either mode can be used at any time.

The actual operation of the cursor definition and positioning proceeds as follows. The operator commands the overall system onto the cursor operating mode by means of the IOCC. He then selects, again by means of the IOCC, in which of the two modes he wishes to operate. When first commanded into cursor mode, the data processor will instantly produce a cursor approximately 2 inches square in the center of the screen. The operator applies the light pen to the center of the cursor area and presses a button on the body of the light pen. At that time, a special symbol called the light pen target, will appear in the center of the cursor area. The location of the light pen target is defined by two 9-bit words transmitted from the data processor. The target is a bright white square made up of 8 picture elements wide by 8 TV lines high. This square will always be full white in intensity. Surrounding this white square will be an area that will always be full black. The width of the black area is 2 pixels on each side of the square and 2 TV lines on top and bottom. This combination assures that the light pen target will always be detectable no matter what the basic image content is on the screen of the display. The light pen will pick up information from an area of approximately one picture element wide by one TV line high.

In the move cursor mode, the data processor is alerted to the position of the light pen in the light pen target. The data processor then recalculates the cursor and target position and outputs this information to the hardware cursor generator. The square and cursor appear to follow the movement of the light pen and the operator can position the cursor to any location on the screen by "dragging" the light pen target in the direction of desired movement.

In the cursor modify mode, the operator again applies his light pen to the center of the cursor area. When he presses the switch on the light pen, the light pen symbol appears. As he moves the light pen in this mode, the symbol follows but the cursor remains stationary. When the symbol meets one of the corners of the cursor, that corner of the cursor will move in the direction of travel of the light pen target as controlled by the light pen. Once he has established the proper position for this line, he releases his light pen switch. When he reinitiates the light pen switch the light pen target will appear in the center of the new cursor area. The operator may then move the light pen target to any other corner of the cursor and selectively modify as required. There is no restriction on either movement or modify sequences and the operator may perform the appropriate tasks in any manner he desires. The computer will respond to any target hits that occur while the switch is depressed. If the operator moves the light pen too fast for the data processor to follow, the light pen target will stop at the last location, if no other target hits occur, and the operator need only return the pen to the target to continue on. The speed of the system in all cases is such that the operator can view the progress of the cursor movements. The reliability and accuracy of the light pen cursor control system is equal to that obtained with X, Y corner position entry using the IOCC unit.

2.6.3 HIGH RESOLUTION STRIP FILM CAMERA

The high resolution strip film camera provides the following characteristics:

- Simultaneous operation with the companion color display system, thus minimizing the data transfers required and providing a monitor of the data being recorded.

- Film width of 9-1/2 inches. Film length of 200 feet. Mountable film cassettes for easy film switching.
- Black and white or color film.
- Brightness resolution of 32 levels for each of the three primary colors. Spatial resolution of 2400 elements in 9 inches with a 1:1 "square" aspect ratio.
- Writing rate of 30 lines/sec in black and white and 10 lines/sec in color for any line length.
- Mode selection and synchronization with the display accomplished with digital logic signals.

2.6.4 INTERACTIVE OPERATOR CONTROL CONSOLE (IOCC)

The proper man-machine interface for the control and monitoring of the Data Analysis System functions is a key to the successful operation of the system. This interface provides a central point of control, easy input and display of control and monitor parameters, interactive bidirectional responses, and a high degree of flexibility to accomplish a wide variety of image processing tasks. This capability is provided by the control panel of the Interactive Operator Control Console (IOCC).

The IOCC provides a highly flexible control panel which provides logically 800 switches, each of which can assume one of 64 positions. Each such switch is displayed as a letter, character, or numeral, and can be changed either by the operator or by the processor. The entire display, or selected portion, can be completely changed by the processor in less than a second. Direct correspondence between the processor, the display, and the keyboard marker assures absolute communications and rapid access to any position.

The display area in operation is typically divided into areas of labelled control input values, which provide an operator checklist, labelled data values (which provide monitoring), error message output or identification input, and operator mode selection and status display output. The IOCC automatically corrects illegal operator requests or entries, which provide

both prompting for the operator and security of the displayed control panel. In the upward scroll mode, the IOCC serves as a direct replacement for the typical teletype operation, and thus supports coding previously developed for ASR33 operation. Included on the keyboard of the IOCC are 12 action-initiator switches which interface directly with the processor and interface logic.

Section 3

ERL-DAS SOFTWARE

3.1 THE MSDS PROGRAMS

Digital image data from the MSDS multispectral scanner is recorded in the aircraft onto analog magnetic tape in a 14-track format. On each of the MSS data channels, tracks one to twelve, two spectral channels are recorded per track. Track thirteen contains housekeeping data and track fourteen contains an IRIG-A time code corresponding to the time of recording.

A software system for use with the ERL-DAS has been developed to process this image data into a form useful to scientific investigators. The principal tasks include the following:

- Quick-look color display of the data
- Copy of selected portions of the data onto computer-compatible digital magnetic tape for use in subsequent detailed analysis
- Select training samples from the displayed test areas

Three separate programs are used to accomplish these tasks - the MDCV, TSMS, and TCMS programs.

3.1.1 MDCV (DATA CONVERT) PROGRAM DESCRIPTION

The MDCV program is the first step in the processing of the MSDS image data to yield a quick-look display of the images and support training sample selection.

This program operates on MSS sensor data to produce quick-look image displays and to produce formatted digital data tapes containing image information. The data source is the twenty-six channel, multiplexed, fourteen track magnetic tape, which is recorded at a constant density of 10,000 bits/inch. In addition to the digital recording and display of data, the MDCV program

is used to (1) select a set of up to twenty-four image channels, (2) logically combine them into one channel, and (3) display and/or record the resulting data.

The image displayed will be the image selected during the image-selection operation, and will be converted to color either directly as part of the selection operation or by a color scale in the display routine. This display can embrace any portion (at full resolution) of the image.

3.1.2 TSMS (TRAINING SAMPLE SELECT) PROGRAM DESCRIPTION

The TSMS program is an image display program which uses an image input tape, the color strip film camera, the color monitor, the cursor hardware, the line printer, the IOCC and the Varian 620/f (16K words). Program control is implemented through the Interactive Operator Control Console (IOCC) subsystem, and complete control of input, image manipulation, display/record, and output may be exercised from the console.

This program takes image data recorded on digital tape, processes this data, and presents the data to the color display and strip film recorder. Training samples can be identified and selected with the cursor on the display. This data is saved for subsequent use by the TCMS program.

The program includes a complete color study routine to modify color scales, a cursor display package to delineate sub-areas of special interest, and a training sample print and tape write routine to record the coordinates of these sub-areas.

3.1.3 TCMS (TAPE COPY) PROGRAM DESCRIPTION

The Tape Copy (TCMS) program is used to read the 26 channel/multiplexed 13-track analog MSDS data tapes and record the data on digital tape for subsequent processing. The multiplexed thirteen track analog tapes are recorded at a constant bit density of 10,000 bits per inch per channel. For MSDS data this is about 16,200 data words per inch and at a playback rate of 3"/sec is 48,000 data words/sec.

For optimal utilization of the MS data the MDCV and TSMS programs may be used to identify areas of interest to be copied on digital tape for further processing. The TCMS program finds the requested interval on the analog tape and copies out that portion of the data. IOCC control allows the selection of MS scanner channels to be copied.

3.2 THE S192 PROCESSING PROGRAMS

Image data from the source tape is recorded on PCM encoded analog tape by the Data reformatter assembly. A software system for use with the ERL-DAS has been developed to process this image data into a form useful for scientific investigators. The principal tasks include the following:

- Quick-look color display of the data
- Correction of geometric distortion
- Select training samples from the displayed test areas.
- Copy of selected portions of the data onto computer compatible digital magnetic tape for use in subsequent data analysis.

Four programs are used to accomplish these tasks: the SDCV, SCOR, TSSL and TCSL.

3.2.1 SDCV (DATA CONVERT) PROGRAM DESCRIPTION

The SDCV program is the first step in the processing of the S192 image data to yield scan-converted display of the images and support training sample selection.

This program operates on S192 sensor data to produce quick-look image displays and to produce formatted digital data tapes containing image information. The data source is the twenty-six channel, multiplexed, four-track magnetic tape, which is recorded at a constant density of 10,000 bits/inch.

In addition to the digital recording and display of data, the SDCV program is used to (1) select a set of up to twenty-four image channels, (2) logically combine them into one channel, and (3) correct the input channel scans for geometric distortion. The distortion correction function is described in detail in the section entitled The Scan Correction Program.

3.2.2 SCOR (SCAN CORRECTION) PROGRAM DESCRIPTION

The SCOR program provides the link between the Data Convert and the Training Sample Select programs to complete the scan conversion process for the S192 image data. The two data tapes produced by the SDCV program must be processed to produce the TSSL input tapes. In two separate operations the center and the edge data (each recorded on a magnetic tape) are converted to yield the two output magnetic tapes.

This requires reading the SDCV produced tapes, completing the S192 scan correction, reformatting and writing two output tapes which will be used by the TSSL program for display and selection of training samples.

3.2.3 TSSL (TRAINING SAMPLE SELECT)

The TSSL program is an image display program which uses two image input tapes, the color strip film camera, the color monitor, the cursor hardware, the line printer, the IOCC and the Varian 620/f (16K words). Program control is implemented through the Interactive Operator Control Console (IOCC) subsystem, and complete control of input, image manipulation, display/record, and output may be exercised from the console.

This program takes image data recorded on two digital tapes, merges and processes this data, and presents the data to the color display and strip film recorder. Training samples can be identified and selected with the cursor on the display. This data is saved for subsequent use by the TCSL program.

The program includes a complete color study routine to modify color scales, a cursor display package to delineate sub-areas of special interest, and a training sample print routine to record the coordinates of these sub-areas.

3.2.4 TCSL (TAPE COPY) PROGRAM DESCRIPTION

The Tape Copy (TCSL) program is used to read the 26 channel/multiplexed 13-channel analog S192 data tapes and record the data on digital tape for subsequent processing. The multiplexed thirteen channel analog tapes are recorded a constant bit density of 10,000 bits per inch per channel. For S192 data this is about 17,500 data words per inch and at a playback rate of 6"/sec is 105,000 data words/sec.

For optimal utilization of S192 data, the SDCV, SCOR and TSSL programs may be used to identify data areas of interest to be copied on digital tape. The TCSL program finds the requested interval on the analog tape and copies out that portion of data. IOCC control allows the selection of S192 channels to be copied.

3.3 THE PMIS PROCESSING PROGRAMS

The ERL-DAS has two major computer programs to process data from the Passive Microwave Imaging System (PMIS). These are PMIS DATA convert and PMIS DATA select.

3.3.1 PMIS DATA CONVERT

The Data Convert Program extracts pertinent data from the PMIS PCM input bit stream, the ADAS input bit stream and the IRIG-A time code channel. The output consists of either scan or temperature-map digital tapes for subsequent analysis by the PMIS Data Select Program, a real-time CRT image display, a real-time numeric display of support data and real time ADAS data line printer listings.

This program is an operator-oriented extraction program which reads PMIS data from an FR2000 analog tape drive and writes the data on digital tape. CONVERT also allows display of microwave radiometer image data on a color CRT and display of system parameters and support data on a numeric CRT. The data copied onto the digital tape contains all essential information from the separate input data streams and is corrected for all geometric and radiometric errors.

3.3.2 THE PMIS DATA SELECT PROGRAM

The Data Select program processes digital tapes created by the PMIS Data Convert Program, displaying and/or recording annotated images while simultaneously supplying all support data to the operator on the numeric display.

I/O hardware utilized by the SELECT program consists of only five devices. Data is input from the right-hand digital tape drive. Control variables are set in the program by the operator through the numeric display. Image data, together with the associated color scales and support annotation, is output to the color CRT and/or the strip-film color recorder. The system parameters, including scan number, time and so forth, are output to the numeric display. Lastly, the color CRT cursor hardware is used by the program to enclose areas of interest specified by the operator.

A number of display options are available to the operator. Data can be displayed either in black and white or color images in one field or three fields. Selected brightness temperature ranges can be displayed independently in each of the three fields. Data in any given field can be fitted to any one of eight separate color tables. Each field can be set to display microwave data in any one of four standard modes - vertical brightness temperature (V), horizontal brightness temperature (H), the average of the two brightness temperatures (A) and the difference between the vertical and horizontal brightness temperatures. In addition, any portion of the display which is surrounded by the CRT cursor may be expanded to fill the entire screen.

3.4 THE OPTICAL PROGRAM (OSSS) PROGRAM DESCRIPTION

The optical processing program, OSSS, provides the processing functions associated with the multiband optical input subsystem (MOS) of the Earth Resources Laboratory Data Analysis Station ERL-DAS. The input of scanned image data from up to four film gates, the registration of two images, the color separation of a color transparency, and the output of this image data onto computer-compatible magnetic tape, color display, and color film recorder are supported.

All the control and processing functions for the input and output of optical images are supported by the OSSS program. The MOS system can scan and digitize up to four film gates over a format size of 1 x 1 inch to 4.5 x 4.5 inches. The 1023 x 1023 raster scan can be placed anywhere in the 4.5 x 4.5 inch format. The input data can be electronically registered during the scanning process such that the digital data from the MOS is in register upon entry to the computer. The data from the MOS is presented first in the sequence of the film gates chosen (these may be any order chosen), then in sequence of the horizontal positions starting at the left side of the raster, and then in sequence of the horizontal lines starting at the top of the raster.

The program has two principal operating modes - the sequence mode and the registration mode, using the IOCC to select all parameters. After the appropriate interrupt switch is depressed, the program first sets up the MOS electronics from the parameter input from the IOCC, then sequentially collects the horizontal lines. Each line is processed as requested and then sent to the selected output devices - the color display, film recorder and magnetic tape.

In the sequence mode, the data from up to the first three film gates are used for the green, red and blue channels of the display or recorder. In the registration mode, the standard (reference) film gate is displayed in green and the image to be registered is displayed in red facilitating selection of IOCC registration parameters.

A software correction for optics vignetting and non-uniformity is included in the program.

3.5 INDEPENDENT HANDLERS

The ERL-DAS software system provides several independent handlers which are incorporated into the main ERL-DAS program or may be utilized in expansion programs.

3.5.1 THE INTERACTIVE OPERATOR CONTROL CONSOLE (IOCC) HANDLER

The Interactive Operator Control Console Numeric Display Handler is a general purpose I/O control package of the Earth Resources Laboratory Data

Data Analysis Station system software. It is designed to completely handle numeric communication with the operator/user on a demand-only interrupt basis.

The handler communicates directly with the Beehive Instruments numeric display using interrupt levels three and four in Priority Interrupt Module Two as input and output interrupts, respectively. Control of the I/O is accomplished according to externally defined tables.

The Input Interrupt Subroutine allows selected operator input to change control data values of various formats, including special formats which are defined by external special subroutines.

The Output Interrupt Subroutine handles the maintenance of output interrupt sequences as generated by the user program. The numeric display screen consists of twenty lines of forty characters each. If a given line has no new characters to be updated the Output Interrupt Subroutine skips that line and goes onto the next. Upon completion of the output update sequence, the Output Interrupt Subroutine returns the numeric display cursor to the location on the screen at which it previously resided. The Input Interrupt Subroutine is inhibited during all output interrupt sequences; any input requests received during an output sequence are saved until the output sequence is completed and are then processed.

The Output Sequence Start Subroutine generates output update sequences according to control parameters passed as arguments in the call statement. Where appropriate, it clears the numeric display screen at the start of the output update sequence. Updates of any single line, any sequential group of lines, or the entire screen of twenty lines are allowable.

3.5.2 ADAS INPUT HANDLER

The ADAS input handler is a general purpose utility package of the Earth Resources Laboratory Data Analysis Station System software. Data from the ADAS input bitstream is decoded and assembled into binary words which are externally available to the user program.

The Handler interprets ADAS data consisting of 96 character frames input to the computer in 24 four-character words forty times every second. Interrupt levels 1 and 2 in Priority Interrupt Module No. 1 are used as the ADAS Work and Sync Interrupts, respectively. There are twenty-four word-interrupts between each sync interrupt.

3.5.3 THE CURSOR LIGHT PEN HANDLER

The Cursor/Light Pen Handler is an independent software package designed to support the light pen I/O hardware and the CRT cursor hardware of the Earth Resources Laboratory Data Analysis Station. It can be connected by the user program to any one of the eight interrupt switches on the numeric display console.

The handler fully supports the light pen I/O hardware and the cursor hardware. The cursor portion extracts the cursor corner coordinate data from an externally defined buffer, assembles a cursor overlay and outputs it to the display. The overlay consists of four start-stop X coordinates on each line of the display. Because two fields (A and B) interlace to form the display, the coordinates are calculated and output for first one field and then the other. Thus, all odd lines are assembled and output, and then all even lines are assembled and output. The cursor overlay is a 512 by 512 grid, with the origin (0,0) being defined as the lower left corner of the display. A buffer of 1024 words must be externally supplied to the handler.

The light pen I/O portion is activated any time the button on the light pen is depressed. When "hits," or input target coordinates are sensed by the hardware and sent to the computer, they are accepted, filtered to remove any "jitter" or noise, and output to the display to move the target accordingly. The coordinates of the cursor are then altered as necessary and displayed on the numeric display in externally defined positions.

When the handler is set to the "fixed geometry" mode of operation, the cursor coordinates are changed so as to maintain the light pen target in the center of the cursor; when the handler is set to the "variable geometry" mode only the coordinates of the cursor corner covered by the light pen target are altered.

3.5.4 THE PCM HANDLER

The DAS includes an input port which will accept PCM bit-serial data over a rate range of nominally 100 to 100,000 bits per second. The data is presented to the computer in parallel with from 5 to 16 bits per word, as selected by the software. All sync detection and decommutation is done in the software.

The PCM Handler is a general purpose utility routine (DAS) software package. The data from the PCM input part of the DAS is initiated, synchronized to the sync pattern, sync-checked, and loaded into buffers for decommutation and analysis in the user program. Word lengths of either 8 to 10 bits are supported. It is used in the 10-bit mode in the PMIS Data Convert Program.

3.5.5 THE CAMERA ANNOTATION HANDLER

The Camera Annotation Handler is a general purpose utility package of the Earth Resources Laboratory Data Analysis Station system software. It is designed to supply character annotation, color scales and software cursor images for any field display of array data on the color CRT. Both color scale and character annotation can be displayed simultaneously in up to ten separate margins/fields, as well as up to ten separate cursor overlays on the displayed data itself.

The Camera Annotation Handler consists of initialization and line subroutines for character annotation, color scale annotation and software cursor overlays. Since a call to a deactivated field of any line maintenance subroutine effects no change to the output data, they may be called at all times in the line write sequence, whether they are needed or not. Combinations of all three, including multiples of the individual line maintenance subroutines, can be accomplished in any manner the user wishes.

The Camera Annotation Handler consists of initialization and line subroutines for character annotation, color scale annotation and software cursor overlays.

3.5.6 MOS

The Varian Master Operating System (MOS) is a versatile batch processing operating system designed to be utilized with the ERL-DAS system configuration.

MOS is divided into resident and nonresident partitions. The resident partition comprises the following:

- a. Resident monitor
- b. Absolute loader
- c. I/O assignment tables
- d. System flags and parameters
- e. Core dump

The nonresident partitions may be classified in three basic groups shown below.

- a. Control Programs
 1. Executive - job control processor and system control
 2. System Loader - linking and relocating loading of system and user programs
 3. I/O control - dispatching of I/O requests and device driving
- b. Support Programs
 1. Math and support library
 2. Concordance program
 3. Debugging program
 4. File editing program
 5. File maintenance program
 6. System preparation program (operates in stand-alone mode)
- c. Language Processors
 1. DAS MR assembler
 - b. FORTRAN IV compiler

The system preparation program is a stand-alone support program of MOS contained on punched cards. It creates a system file on magnetic tape tailored to hardware and software requirements of the installation.

Section 4

APPLICABLE DOCUMENTATION

This section lists all documentation applicable to the Earth Resources Laboratory Data Analysis System.

4.1 REFERENCE DOCUMENTS

Design Review Report for Earth Resources Laboratory Data Analysis System, August 1971.

Monthly Progress Reports.

4.2 O&M MANUAL

Operation and Maintenance Technical Manual, 1746M-1.

Volume I - Hardware System

Volume II - Software System

4.2.1 SUPPLEMENTARY LISTS AND DATA SHEETS

Module Wire List, Volume I

Pin List, Volume II (Card Cases A and B)

Pin List, Volume III (Card Cases C and D)

Pin List, Volume IV (Card Cases E through P except "O")

Pin List, Volume V (Card Cases Q and R)

Cable Wire List, Volume VI (Cables)

Special-Purpose Card Data, Volume VII

4.2.2 SPECIAL-PURPOSE MANUALS

a. Computer and Peripherals

Varian 620F Maintenance Manual, Volumes I and II

Varian Buffer Interface Controller Manual, No. 98A 9902113

Varian I/O Signal Wiring System Memo, No. PB-4508
 Varian Optional Instruction Set Manual, No. 98A 9903430
 Varian Priority Interrupt Module Manual, No. 99A 9902423
 Varian 620F Computer Handbook, Bulletin No. 113A 9809908-002
 Varian Magnetic Tape Controller Manual, No. 98A 0611
 Varian Magnetic Tape Controller Schematic Diagrams,
 Drawing No. 91C0319
 Varian Priority Memory Access, No. 98A 9908 420
 Varian MOS Reference Manual, No. 98A 9952 090
 Ampex Technical Manual, TM16 Tape Transport, No. 3110469-01,
 Revision A
 Data Products Technical Manual, Model 2410 Line Printer,
 Volumes I and II
 Bridge-Data Products Reference and Maintenance Manual,
 Bridge Data Card Reader Model 8000 Series, No. 10060000

b. FR2000 Analog Tape Transport

Ampex FR2000 Recorder/Reproducer Tape Transport and
 Control Circuit Maintenance Manual No. 1801945
 Ampex FR2000 Recorder/Reproducer Tape Transport
 Parts List Manual, No. 1802296
 Ampex FR2000 Recorder/Reproducer Operator System
 Manual, No. 1802013
 Ampex ES200 Electronics Manual, No. 1802001
 Ampex Footage Counter Manual, No. 1802212-01

c. Interactive Operator Control Console (IOCC)

Beehive Medical Electronics Reference Manual for Beehive
 Terminals Models I, II, and III, No. TM-10A
 Ball Brothers Instruction Manual, TE Video Monitor,
 No. TM69-01, Revision C.

d. Time Code Reader Generator

CGS Datametrics Time Code Generator Reader Model SP-400A
 Maintenance Manual

e. Strip Film Camera

HRB Singer Operation and Limited Maintenance Manual,
 CRT50 Color Film Recorder Model CFR-102, No. 4432-M2
 One set reproducible schematics for Model CFR-102 CRT
 Color Film Recorder

f. Display

Conrac Color Television Monitor Model RAM14 Installation
 and Operating Instructions
 Data Disc FPD Memory System I/O Manual
 Data Disc FPD Memory System Service Manual
 AGC Interface Manual, SGD2000 Series Displays
 Instruments Display Inc. Light Pen Electronics Manual,
 No. M-2004A

g. Power Supplies

Trio Laboratories Instruction Manual, 600 Series Power
 Supplies
 Lambda Instruction Manual, Rack Adapter LRA-8, LRA-9,
 LRA-10, LRA-11
 Lambda Instruction Manual, Lambda Standard Power Systems
 Lambda Instruction Manual, LCS-4 Series
 Lambda Instruction Manual, Models LXS-C-5-0V, LXS-C-6,
 LXS-C-12, LXS-C-15 (-15 V)
 Lambda Instruction Manual, Model LM-E Package (+15 V)
 Lambda Instruction Manual, Model LV-E Series (+5 V)

h. Optical System

Perkin Elmer "Procedures for Cleaning, Realignment, Refocus,
 and Maintenance of the Multispectral Optical"
 Pacific Photometric Instruments Instruction Manual, Negative
 High Voltage Power Supply, Model 203
 Pacific Photometric Instruments PMT Electronics Manual,
 Model 1A12
 Beta Instruments Flying Spot Scanner Instruction Manual,
 PD1200/1400

i. AGC-Generated Schematics and Block Diagrams

<u>Drawing No.</u>	<u>Title</u>
1393550 (22 sheets)	PMA/BTC Line Driver/Receiver, Card Assembly
1393551	620F, PMA/BTC Driver/Receivers
1393552 (23 sheets)	PMA/BTC Controller Modification
1393553 (22 sheets)	620F BTC Modification
1393557	Wiring Harness, Color Display Front Panel - Series SG-D2000
1393558	Front Panel Interface
1393559	Block Diagram, SG-D Series 2XXX Display Unit
1393560 (Sheet 1 of 9)	Timing Logic
(Sheet 2 of 9)	TV Line Address, Compare Logic
(Sheet 3 of 9)	Disc Load Logic
(Sheet 4 of 9)	Disc Output Assembly and Steer Logic
(Sheet 5 of 9)	Color Algorithm Input Logic
(Sheet 6 of 9)	Color Algorithm, Read/Write Logic
(Sheet 7 of 9)	Mode Control Logic
(Sheet 8 of 9)	Video Output Multiplexer
(Sheet 9 of 9)	Logic Diagram, Graphic Overlay
1393563	Module Location Diagram - Multispectral, PCM, ADAS, Optical Input Interfacing Circuits
1393564	Module Location Diagram for Options and Display, ERL-DAS
1393565 (11 sheets)	Optical Input, Logic Diagrams
1393571	Equipment Identification, ERL-DAS
1393572	System Block Diagram, ERL-DAS
1393573 (Sheet 1 of 5)	Display & Option I/O Interface, ERL-DAS
(Sheet 2 of 5)	Display & Option I/O Interface, ERL-DAS
(Sheet 3 of 5)	Display & Option I/O Interface, ERL-DAS
(Sheet 4 of 5)	Display & Option I/O Interface, ERL-DAS
(Sheet 5 of 5)	512 Horiz. Position (Synchronous) Counter Display & Option I/O Interface, ERL-DAS

<u>Drawing No.</u>	<u>Title</u>
1393574	Block Diagram Cursor Interface, ERL-DAS
1393575 (Sheet 1 of 4)	Control Cursor Interface, ERL-DAS
(Sheet 2 of 4)	Cursor Storage, Cursor Interface, ERL-DAS
(Sheet 3 of 4)	Comparator, Cursor Interface, ERL-DAS
(Sheet 4 of 4)	Output, Cursor Interface, ERL-DAS
1393576	Block Diagram, Light Pen Interface, ERL-DAS
1393577 (Sheet 1 of 2)	Target Generator, Light Pen Interface, ERL-DAS
(Sheet 2 of 2)	Target Position Detector, Light Pen Interface, ERL-DAS
1393578	Block Diagram, Strip Film Recorder Interface, ERL-DAS
1393579 (Sheet 1 of 2)	Control, Strip Film Recorder Interface, ERL-DAS
(Sheet 2 of 2)	Strip Film Recorder Interface, ERL-DAS
1393580	IOCC Interface, ERL-DAS
1393581	Block Diagram, Multispectral Input Subsystem
1393582	Input System, I/O Line Driver/Recorder, ERL-DAS
1393583	Input System, I/O Decoder, ERL-DAS
1393584	Input System, I/O Status, ERL-DAS
1393585	Input System, I/O Storage, ERL-DAS
1393586	Multiplexer, Multispectral and PCM Data Interface, ERL-DAS
1393587	Channel Sequencer, Multispectral Interface, ERL-DAS
1393588	Request Data in Control Multispectral Interface, ERL-DAS
1393589	Frame Sync Detector Multispectral Interface, ERL-DAS
1393590	Block Diagram, PCM Data and ADAS Interface, ERL-DAS

<u>Drawing No.</u>	<u>Title</u>
1393591	Logic Diagram, PCM Data Interface, ERL-DAS
1393592	Logic Diagram, ADAS Interface, ERL-DAS
1393593	Analog Tape External Control, ERL-DAS
1393594	Block Diagram, Bench Test Unit, ERL-DAS
1393595	Bench Test Unit, ERL-DAS
1393596	Varian Equipment Connections, Rear View, ERL-DAS

Section 5

ERL-DAS SPECIFICATION COMPLIANCE

The ERL-DAS system essentially meets all contractual specifications. The Optical system illumination uniformity was specified to be .5%. It was determined during the development of the optical system that this was beyond the state-of-the-art for optical systems with the number of optical elements contained in the ERL-DAS multispectral optical system.

Since the non-uniformity was inherent in the hardware, a special software correction was added to the optical program enabling achievement of a uniformity of approximately 2 percent. It was determined by NASA technical personnel that this illumination nonuniformity is more than adequate for their applications.

Significant additional software and hardware capability has been delivered in consideration for this specification deviation.

Section 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The Earth Resources Laboratory Data Analysis System provides a valuable research tool in the evaluation of Multispectral, S192, Photographic and PMIS data. The system has been in operational use for approximately three (3) months and has performed quite well.

Emphasis on versatility of both the hardware and software design facilitates system expansion to many specialized data analysis tasks. The many independent software handlers provide building blocks for major processing programs.

6.2 RECOMMENDATIONS

Due to the complexity of the ERL-DAS it is recommended that a two to three week hardware and software training program for NASA and NASA support contractors be contracted with AESC. This training program will enable both software and hardware oriented personnel to better understand and utilize the full ERL-DAS system capability.